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Fiber Length as a Variable Influencing Wet Strength

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as a Variable Influenceing Wet Strength"/

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Abstract

It was desired to discover the influence of fiber length on wet strength obtained by the addition of a resin. The wet strength tests chosen were the tear and tensile, the retention of the resin was also measured. The resin used was melamine formaldehyde acid colliod.

The wet tensile showed no significant drop with decreasing fiber length until the fibers were cut very short. The wet tear was shown to be very sensitive to any change in fiber length. The retention of the resin was relatively unaffected by the fiber length.

Fiber Length as a Variable Influencing Wet Strength

"Literature Survey"

Introduction

By "wet strength" is meant strength which the paper has after it is completely saturated with water. For some papers this may require soaking only a few minutes while for others it may take 16 hours or even longer. The use of wetting agents has been suggested for shortening the period of soaking. Some papers appear to have wet strength due to a high resistance to water; however, if these papers are soaked a sufficiently long time to saturate them it may be found that they actually have very little wet strength.

The degree of wet strength is often given as the percentage of the dry strength, although it has been shown that when resins such as urea formaldehyde and melamine formaldehyde are added the wet strength is generally quite independent of the dry strength.

Of the resins used for the wet strength treatment of paper the most commonly used ones are thermosetting and the majority of these can be separated into three distinct types: (1) melamine formaldehyde acid colloid

(cationic), (2) anionic urea formaldehyde and (3) cationic urea formaldehyde.

The resin can be added to the pulp anytime after it enters the beater and before it is formed into a sheet, however it is generally agreed that the later the resin is added prior to sheet formation, the better the wet strength efficiency, but there appear to be some exceptions to this. The amounts of resin added are generally in the range of 0.5 to 5.0% on the dry fiber basis. Sometimes the resin is applyed by means of a size press, but this is a special case which involves impregnation and will not be considered here.

The resin develops under the effect of heat with acid acting as a catalyst. It is often the case that the resin has not completely cured by the time the paper leaves the paper machine. When this happens the wet strength of the paper increases with age, reaching its maximum after four days to a month depending upon the pH of the sheet and the temperature at which it was dried.

Variables

The nature of the furnish quite naturally has an effect on the wet strength developed. In general, unbleached pulps will give a sheet of higher wet strength

than bleached pulps. The wet strength developed from Kraft and Sulphite seems to be about the same, although more of the resin is bound by the Kraft fiber than by the Sulphite.

The drying temperature and pH of the sheet have a considerable effect on the rate of curing of the resin. The pH of the stock also has an effect on the amount of resin picked up by the pulp.

With a bleached pulp furnish very little wet strength can be obtained with a pH above 6, however with unbleached pulp a fair amount of wet strength can be obtained with a pH around 7. The pH can be lowered by the use of paper-makers alum, aluminium chloride or minerial acids.

Other variables include salts in the furnish water, temperature and consistency of the stock, and also the contact time of the resin between addition and sheet formation. The temperature and consistency of the stock seem to have little influence on the wet strength obtained. The time of contact is quite important, it should be long enough to give the cellulose time to pick up the resin but not so long that it allows the resin time to dissolve.

The effect of salts in the furnish depends upon the type of resin used. Anions have an adverse effect

upon the efficiency of the cationic resins and cations have a similar effect upon the anionic resins. The valence of the ions is also a determining factor. It has been sujested that the potency of the anion increases with valency (mono, di, tri,) roughly in the magnitude of 1:10:30.(5)

It should be pointed out here that the optimum conditions for resin retention do not always coincide with optimum conditions for wet strength.

It is generally agreed that the retention and also the wet strength obtained goes up with increased beating, at least to a point. This is probably due to the increased surface giving more of an opertunity for resin retention and bonding. Very little work has been done on the influence of fiber length and what there is available is divided in opinion and not very conclusive. One thing that does seem certain is that it is possible to get better retention of the resin with short fibers or a mixture of short and long fibers then if long fibers alone were used. This does not however insure better wet strength. The presence of a large porportion of fines can cause both the wet strength and the retention of resin in the sheet to fall. This is due to the fact that the fines having a large surface area relative to their weight adsorb a large amount of resin

that is lost when they pass through the wire.

Wet Strength Mechanism

Bursztyn[2] was able to show that the resin is deposited on the fibers in the form of small particles which have a size range somewhere near that of the diameter of the fibers.

Microphotographs, retention figures and wet strength results indicate that urea formaldehyde resins are retained mainly as a result of a filtration effect of the fibers.

The strength of a sheet of paper either in the dry or wet state probably arises from a combination of many factors. Since it appears to be impossible to define these clearly or to separate them sharply, a quantitive determination of the amount which each contributes to the strength of the sheet cannot be made, although it does appear permissible to separate them into two main groups: (a) the ultimate strength of the fibers, and (b) the bonding or adhesion between the fibers.[7]

The ultimate strength of the fibers naturally represents the maximum strength of the paper and is important only when the strength of the bonds is greater than the strength of the fibers. A good relative measure of the

fiber strength can be obtained with the zero span tensile test. A tensile test at a span of one inch or more will give a measure of the adhesion between the fibers providing this is less than the strength of the fibers themselves, which is just about always the case.

Sally and Blockman[7] defined a quantity which they call percent adhesion. This was the tensile at a span of one inch divided by the tensile at zero span. This seems to be a fairly good method for measuring what the resin has done to increase the adhesion between the fibers in the wet state.

By use of the zero span and the one inch span tests it was shown that to get wet strength it was the strength of the bonds between the fibers and not the strength of the fibers that had to be increased, although the strength of the fibers in the wet state was less than in the dry state. These same tests on the untreated sheets and on sheets treated with various amounts of resin showed that the resin increased only the bonding between the fibers and not the strength of the fibers themselves. This was the case for the paper in both the dry and the wet state.

Testing Wet-Strength Paper

Of all the problems involved in testing paper for wet strength a large porportion of them could be classed as problems concerned with wetting the paper. Some of the more prominete of these are; what the paper should be soaked in, how long it should be soaked and whether or not a wetting agent should be used.

TAPPI(9) specifies the use of distilled water or its equivalent. This has the advantage that it is fairly uniform from place to place but it has the possible criticism that it takes the pH of the paper soaked in it and there is evidence that the pH of the water has an effect on the wet strength. Since the resin hydrolyizes faster in acid solution more of the resin will dissolve in water with a low pH than in water with a high pH, thus of two papers with the same wet strength but a different pH the one with the higher pH would appear to have more wet strength after soaking in distilled water. Ordinary tap water is not very suitable because of the variation from place to place. A buffer probably would give the most uniform results but there are also objections to this, such as what pH would simulate actual use conditions more closely.

As for the use of wetting agents this seems quite practical for use as control purposes on hard sized papers. Before the use of a wetting agent is decided upon it should be thoughly investagated to find what difference, if any, it makes in the wet strength of the paper. For most papers a wetting agent can probably be found that will shorten the period of soaking considerably without adversly affecting the wet strength.

The soaking period should be long enough to saturate the paper completely but not so long that the resin will dissolve. For most sized papers these conditions probably overlap and if the paper is saturated some of the resin has probably dissolved, however the difference due to this will be small compared to the difference that would have resulted if the paper had not been completely saturated.

The End

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7. Sally, D. J. and Blockman, A. F. Paper Trade Journal 125 no. 1:35-40 (July 3, 1947)

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9. TAPPI Standard Method T 456 m-49

Planned Experimental Work

An attempt will be made to discover the influence of fiber length on wet strength by measuring the effect of fiber length upon some of the wet strength characteristics of paper made from pulp of different controlled fiber lengths. The rentention of the resin will also be measured, as will the apparent density of the sheet.

The general outline for the experimental work was taken from a paper by Clark[1] in which he analysed the influence of fiber length on the dry strength characteristics of paper.

The pulp used for the experimental work will be an unbeaten bleached Kraft composed largely of Douglas Fir fibers. This pulp was chosen because of the great length and uniform diameter of the Douglas Fir fibers. The fines normally present in the pulp will be removed because they would probably have diameters vastly different from the diameters of the whole fibers. This will be accomplished by running the pulp through a Bauer-McNett fiber classifier and keeping only the fraction that won't pass through a 20 mesh screen. The pulp, with the fines removed, will then be made into sheets and cut into thin strips, thus giving fibers of various length's but

1. Clark, J. d'A Paper Trade Journal 115 , no.26:36 (Dec. 24, 1942)

all of approximately the same diameter. The strips will then be disintegratedand reclassified with 10, 16, 20, and 150 mesh screens in the classifier. These particular screens were chosen because it is desired to find out if the very long fibers, that would remain in the first fraction, held by a 10 mesh screen, would give better wet strength then the slightly shorter but more normal fibers that would be held by the 16 and 20 mesh screens. The last fraction, fibers passing through the 20 mesh screen and held by the 150 mesh screen, would show what wet strength could be obtained with very short fibers.

Test sheets will be made of pulp from each fraction and also from an unfractionated portion of the cut fibers. Sheets will also be made from all the fractions put together in the same relative amounts as they were in the unfractionated pulp. This when compared with the sheets made from the unfractionated pulp will show the influence of the very short, passing through 150 mesh, fibers.

The sheets will be made with various percentages of melamine formaldehyde resin. The first two sets of sheets will be made with 4 and 10 percent resin. Other sheets will be made with different amounts of resin depending upon how the first two sets come out. If there is little change in wet strength between the

4% resin added and the 10% resin added sheets, more sheets will be made with 2% and 20% resin added. If there is an appreciable difference in wet strength between the first two sets then more sheets will be made with 6 and 8 percent resin added. The sheets will be made at a pH of 4.5 which will be obtained with alum.

The sheets will be tested after heating in an oven at 115°C for 15 minutes. It was decided to completely cure the resin by heating in order to make the interval of time between sheet making and testing less critical as the time schedule does not permit ageing of all the sheets for a sufficient length of time to be sure the resin is cured anywhere near completely. The paper will be soaked for 1 hour in distilled water at 72°F. The time of 1 hour was chosen because it was convenient and it was shown by preliminary, experiments that the wet strength did not change appreciatively when the soaking period was increased to three hours.

The apparent density will be calculated from the weight and caliper figures. The resin retained in the sheet will be determined by the Kjeldahl method.

Fibers from each fraction will be measured in order to obtain the average fiber length.

Experimental Work

The planned experimental work was followed except for the following exception. The sheets made from the pulp from all the fractions were omitted because there was such a small amount of pulp passing through the 150 mesh screen that it's effect on the whole was negligible.

Sheetmaking

The sheets were made in the following manner. Sufficient pulp was added to the water in the British Sheet Machine to give a sheet of 1.25g (oven dry). The resin was then added and the stock agitated, the alum was added next and the stock was again agitated. The sheets were drained and removed from the wire in the usual manner. The sheets were pressed immediately in a Noble and Wood Press and dried on a Noble and Wood drier at 250°C.

Sheet Testing

The sheets were tested for wet tensile and wet tear. The wet tensile was tested according to Tappi Standard T 456m-49.

The wet tearing resistance was tested in the following manner. The sheets were cut to the required width of 21/2 inches and ten were clipped together with a paper clip. The starting cut was made while the sheets were dry. This was necessary because the sheets pulled apart instead of slitting when they were wet. The ten sheets were torn at one time.

The resin content of the sheets was determined according to Tappi Standard T 418m-50, the resin manufacturers factor of 2.6 was used to convert organic nitrogen to melamine formaldehyde resin.

Fiber Measurement

Fibers from the four fractions and from the unfractionated pulp were measured by the projection method. The projector was set at such a distance from the screen so that two inches equaled one millimeter, this calibration was accomplished by means of a microscope micrometer. The fibers projected on the screen were measured with a map measurer and the inches converted to millimeters.

The fibers from the different fractions were all fairly uniform in length, with a variation of about

two millimeters in the first fraction being the largest variation. The overall variation in the unfractionated pulp was from .5mm to 5.5mm length.

Conclusions

For the most part the results with the wet tensile showed that moderate differences in fiber length did not have an appreciable effect on the wet strength. The sheets made from the pulp in the first three fractions showed no appreciable differences in wet tensile, however the wet tensile was considerably lower in the sheets made from the pulp in the fourth fraction. This was the case with both sets of sheets, those made with 4% resin added and those made with 10% resin added.

As would be expected because of the sensitivity of the tear test to fiber length the wet tearing resistance showed a wide difference between sheets from the different fractions. As in the case of the wet tensile the trends indicated with the 4% resin sheets were duplicated with the 10% resin sheets.

The fiber length seemed to have very little influence on the retention of the resin except that the unfractionated pulp retained much less of the resin,

in both sets, than any of the four fractions. A possible explanation for this is that the very short fibers that are lost when the pulp is fractionated take up a large amount of the resin and then are lost in the Sheet-making process.

The End

Table 1

Sheets Made With 4% Resin

Mesh Screen	Fiber Length	Density	Wet Tear	Wet Tensile	Resin Content
+ 10	4.00mm	.425g/cc	59.4g	1.56lbs/in	.485%
-10 +16	3.28mm	.470g/cc	48.0g	1.54lbs/in	.486%
-16 +20	2.16mm	.485g/cc	32.0g	1.42lbs/in	.430%
-20 +150	1.18mm	.480g/cc	14.0g	.91lbs/in	.486%
unfrac-tionated	2.40mm	.458g/cc	40.0g	1.56lbs/in	.227%

Table 2

Sheets Made With 10% Resin

Mesh Screen	Fiber Length	Density	Wet Tear	Wet Tensile	Resin Content
+10	4.00mm	.445g/cc	80g	2.46lbs/in	.55%
-10 +16	3.28mm	.495g/ec	72g	2.94lbs/in	.502%
-16 +20	2.16mm	.540g/cc	58g	2.94lbs/in	.795%
-20 +150	1.18mm	.540g/cc	38g	2.16lbs/in	.584%
unfrac-tionated	2.40mm	.470g/cc	56g	1.78lbs/in	.388%